PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : G01S 13/93, 7/04, 13/87

A1

(11) International Publication Number: WO 89/06808

(43) International Publication Date: 27 July 1989 (27.07.89)

(21) International Application Number: PCT/IT89/00002

(22) International Filing Date: 16 January 1989 (16.01.89)

(31) Priority Application Number: 47545 A/88

(32) Priority Date: 18 January 1988 (18.01.88)

(33) Priority Country: IT

(71)(72) Applicant and Inventor: PAOLETTI, Paolo, Alberto [IT/IT]; Via Luigi Rizzo, 62, I-00136 Rome (IT).

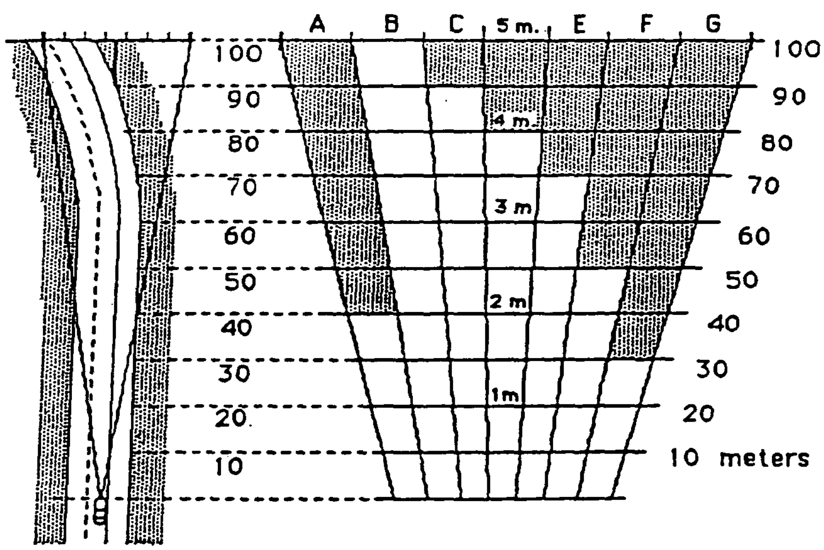
(74) Agents: TALIERCIO, Antonio et al.; Ing. Barzanò & Zanardo S.p.A., Via Piemonte, 26, I-00187 Rome (IT).

(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BG, BJ (OAPI patent), BR, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE, DE (European patent), DK, FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: VEHICULAR ANTICOLLISION RADAR SYSTEM



(57) Abstract

The space ahead of a moving vehicle is irradiated in sectors (A-G) by a plurality of CW solid state radar devices mounted as an array across the front of the vehicle, such that adjacent lobes of each beam may overlap. The radar signal comprises a CW beam modulated intermittently by a slightly offset frequency to produce 'pulses' which when reflected from obstacles within respective sectors (A-G) are detected by mixer diodes in one, or two adjacent radar devices after a time delay which, when measured, yields a distance to the obstacle. Obstacles so detected may be displayed in two dimensions within their respective sector (A-G) on a display projected ont the windscreen.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT Austria
AU Australia
BB Barbados
BE Belgium
BG Bulgaria
BJ Benin
BR Brazil
CF Central African Republic
CG Congo
CH Switzerland
CM Cameroon
DE Germany, Federal Republic of
DK Denmark
FI Finland
FR France
GA Gabon
GB United Kingdom
HU Hungary
IT Italy
JP Japan
KP Democratic People's Republic of Korea
KR Republic of Korea
LI Liechtenstein
LK Sri Lanka
LU Luxembourg
MC Monaco
MG Madagascar
ML Mali
MR Mauritania
MW Malawi
NL Netherlands
NO Norway
RO Romania
SD Sudan
SE Sweden
SN Senegal
SU Soviet Union
TD Chad
TG Togo
US United States of America

VEHICULAR ANTICOLLISION RADAR SYSTEM

To drive a vehicle in the fog with no visibility, it is not sufficient an equipment signalling only the presence of obstacles or free way before the vehicle, even if completed with the indication of the minimum distance between the obstacles and the vehicle, but it is also necessary to know their location with more detailes, so that it be possible to take decisions about the movements to perform, expecially in proximity of curves, if to the right hand side or to the left hand side or also to overtake if there is ahead a too slow vehicle. Therefore it is required to indicate the geometry of the free space in front of the vehicle by employing a bidimensional quadrant, consisting for example of numerous spots that lighten red or green in each narrow sector ahead if there is or there is not an obstacle (figure 1). Such a quadrant could be located upon the dashpanel in such a manner that the luminous image be reflected by the windscreen toward the driver, thus consenting him to look at it together with the road.

In other words the problem is to measure the coordinates of eventual obstacles. We will use polar coordinates: with reference to figure 3, we will call distance (from obstacle) the measure of the radial vector $R = OH$ and declination the angle Z formed by the radial vector with the vertical axis y.

The measure of R may be deduced from the measure of the time t required by an electromagnetic radiation to propagate

from the antenna located in O up to the obstacle H, reflected by H and back into O. Given c the propagation velocity, we get:
$R = c \cdot t / 2$.

For measuring the angle Z we may employ n microwave beams irradiated by small fixed antennas, slightly divergent, for consenting the exploration of the areas belonging to 2n-1 sectors, as indicated for example in figure 2 where n=3. In this figure we may distinguish five angular sectors and therefore quantize the angle Z in five parts: if an obstacle is located for instance in the center line of sector B, it will be detected only through the beam B; if it is located in intermediate position, for instance in sector A+B, it will be detected by both beam A and beam B.

This technique, that we define "amplitude discrimination", seems recalling that of the monoplulse radar used in authomatic tracking systems, but it is not exact: in fact such systems are effective when there is only one target, but less efficient when the targets are more than one, expecially if the targets are equidistant from radar and are clustered. On the contrary we intend to signal every each obstacle, with an accuracy satisfactory for most practical obstacle configurations. The most difficult configurations to be correctly detected are those with obstacles all aligned at the same distance R from the antennas; but, save particular cases that however do not lessen the safety given by the system, it supplies yet sufficient informations for a cautious driving.

The procedure to be adopted is the following. Let us suppose, for semplicity, n=3 (figure 2): the three beams belong to

the three antennas A, B, C, that are at the same time transmitting and receiving, and therefore connected to respective transmitters and receivers. A short radiofrequency pulse is emitted one at a time by each of the three transmitters, while the three receivers are always abilitated contemporaneously. Let us suppose now that a pulse be emitted only by antenna A and that there is only one obstacle entirely situated in sector A (ref. figure 2), at distance R from antenna: after a certain time the echo consequent to the reflection on the obstacle is received by antenna A, but not by antenna B neither by antenna C; if the obstacle is in sector A+B the echo is received by antennas A and B, but not by antenna C. The next pulse be emitted by antenna B: the same obstacle in sector A+B will reflect an echo received practically at the same instant by antennas B and A and not by antenna C; but if the obstacle is situated in sector B it will reflect an echo received only by antenna B.

It is understood that two and also three distinct aligned obstacles, situated at the same distance R from the antennas and contained one in sector A, the other in sector B and the third in sector C - without affecting sector A+B or sector B+C - can be distinctly recognized by the apparatus, since the system receives at the first time the echo signal only with antenna A, at a second time with antenna B, and at a third time only with antenna C, but never simultaneously with antennas A and B or antennas B and C.

The simultaneous reception happens, for geometrical considerations, when an obstacle is situated in one of the

common sectors, for instance in sector A+B and at the distance R from the antennas. In fact an impulse transmitted by antenna A intercepts the obstacle and returns as an echo to both antenna A and antenna B, and viceversa an impulse transmitted by antenna B intercepts the obstacle and returns as an echo to both antennas B and A. This happens independentely whether sector A and/or sector B are or are not free from obstacles, since it is not possible to distinguish if also sectors A and B are or are not occupied by obstacles at the same distance R, save a further manipulation of signals such to consent also the above said distinction. To avoiding such manipulation it is reasonable to assume the worse case, like that the sectors A and B also contain obstacles aligned with the obstacle in sector A+B at the same distance R: it is therefore necessary to give a signalling equivalent to a single obstacle at the distance R with a span covering all three sectors A, A+B and B. This signalling choice does not constitute a significant limitation of the system: we shall not forget in fact that we operate in the fog, where we have to discourage hazardous manoeuvres. Let us extend now the reasoning to sector C, in which at the same distance R we suppose another obstacle is contained, but none in sector B+C: then the sector B+C will be shown as being free from obstacles, whereas sector C will signal the obstacle. In conclusion with the described beams we obtain full angular information on how to proceed in the fog. In addition road delimiting guard-rails or other detectable surfaces shown on the display will furnish a complete view of the space ahead of the driver; in fact for a full safe driving is necessary the

provision of microwave reflecting surfaces at the edges of roads and transit zones, where missing, to avoid trenches, ravines, etc.

When an obstacle is detected, for example in sector A at distance R = 50 meters, it is foreseen that not only its warning light be lit, but also all the lights beyond it at increasing distances be lit, like shown in figure 1 for all spots pertaining to sector A at R = 50, 60, 70 ... meters. This reflects simply the fact that the obstacle masks all what is in its shade cone, as normally happens in optics. This arrangement has also the advantage to shift into a necessity the excess of signalling previously described about the simultaneous reception.

The execution of the equipment requires three phases: the first phase relates to the study of the electromagnetic propagation and the selection of the microwave devices of the n transmitting-receiving units with the respective antennas. The second phase relates to all those circuits actuating the most adequate modulations, amplifications and combinations of the emitted and received signals, with the scope to get the data required for the computations of R and Z. The third phase consists in the digital elaboration of the multitude of different data (R and Z) related not only to a single obstacle but also to complex obstacle configurations to be indicated on the display; in fact the weak echo signals arriving to the receivers - after an adequate amplification - have necessarely to be interpreted, in accordance with the above described criteria, by means of a dedicated circuit which may be of a digital type and high speed of elaboration: this is feasible without difficulties with more or

less sophisticated technical solutions in view of the desired performance, so that no particular execution is detailed herein. The elaboration may result in a bidimensional display, for instance as that shown in figure 1. Likewise it is useless to digress on weak echo signal amplification from the receivers, since the executions are known by the present technics; the same can be said about transmitters and antennas. In conclusion the execution details of above said parts may vary amply from one construction to another, remaining in any case within the invention concept.

Now we expose, as a significant examplification, the particular selections adopted to provide a simple prototype that can confirm the validity of our system. Let us use three identical resonant cavities gunnplexer at 10 GHz, each of which is able to generate and modulate a radiofrequency signal by means Gunn and varactor diodes, and detect the echo signal by means of the Schottky diode. Small and directional horn type antennas are applied to the cavities, such to form three narrow diverging beams, as shown in figure 2. The Gunn diodes are fed as directed and the cavities are calibrated to the same frequency f_1. An appropriate circuit, called modulator, generates very short tension pulses, each with the duration τ of some tenths of nanoseconds, and provides to send them one at a time to each of the three varactor diodes in sequence; in this manner each cavity at a time oscillates for a short time interval τ at frequency $f_2=f_1+f_b$, where f_b depends by the tension pulse applied to the varactor. A microwave train at frequency f_2 is therefore emitted

for a time τ by one of the antennas, hits the possible obstacle situated at distance R, and a small reflected portion returns into one or more antennas after a time $t = 2 \cdot R/c$ (being c the propagation velocity of the wave train); from the antennas it is conveyed into the corresponding receiving Schottky diodes. But in the meantime also the cavity that had transmitted the short oscillation at frequency f_2 has resumed to oscillate at frequency f_1, and a small portion of this oscillation is also sent to its own Schottky diode, which consequently executes the product of the two above mentioned oscillations at frequencies f_2 and f_1. In conclusion at the output terminal of the Schottky diode of said cavity is present for a time τ a signal of the following type:

$$u(t) = r(t) \cdot m(t) = A_2 \cos(2\pi f_2 t + \phi_2) \cdot A_1 \cos(2\pi f_1 t + \phi_1)$$
$$= A \cos[2\pi (f_2 + f_1) t + (\phi_2 + \phi_1)] + A \cos[2\pi (f_2 - f_1) t + (\phi_2 - \phi_1)]$$

where r(t) is the signal due to echo and m(t) the quantity due to the local oscillation f_1, and where: $(A_2 \cdot A_1 / 2) = A$.

This resultant u(t) is called beat of the two signals r(t) and m(t), and consists of two components of equal amplitude A; but, being $f_1 \equiv f_2 \equiv 10$ GHz, the first component has frequency of about 20 GHz, of no interest and therefore will be filtered out; on the contrary the second component has a much lower frequency, and constitutes one of the three useful signals deriving from the microwave reflections on the obstacle. In fact also the remaining two cavities oscillates at frequency f_1, as we have said, and also for them - in case of echo signal reception with frequency f_2, which happens if the obstacle is in the sector A+B or B+C - is valid the beat effect. In conclusion from the measure of time t between

the instant in which is emitted the short oscillation at frequency f_2 and the instant in which the oscillation at frequency f_b emerges from one of the Schottky diodes, it is simple to obtain the distance R between the cavity and the obstacle with the equation: $R = c \cdot t / 2$.

The use of pulsive signals for the transmission consents to discriminate in depth, meaning that we can identify and distinguish several obstacles successively more far away with a resolution r which is bound to the pulse duration τ by the equation: $r = c \cdot \tau / 2$.

The maximum distance (range) R_{max} having interest to detect the obstacles estabilishes the pulse repetition frequency (P.R.F.), or the pulse timing T (T = 1/P.R.F.), in accordance with equation: $T_{min} = R_{max} / c$. To avoid disadvantageous echo superimpositions (second-time-around echoes) it is necessary to use values T at least twice as much as T_{min}. Thus, having foreseen for our prototype a range R_{max} = 100 meters (resulting T_{min} = 0.67 microseconds), we have selected the value of T equal to 2 microseconds. The figure 4, not to scale, indicates qualitatively the relationships among f_1, f_2, τ, T.

The selected subdivision of R_{max} in segments of 10 nanoseconds each is sufficient to recognize the zones free from obstacles at the various distances (figure 1). To assure distinguibility among obstacles with reciprocal depth distances (i.e. in direction of R) of at least ten meters, it is required a distance resolution r = 10 meters: this means to operate with pulse duration not longer than τ = 67 nanoseconds. Therefore we

have fixed intervals of 67 nanoseconds, equivalent to a wave run of 20 meters between supply and return, and we scan them by means of a counter. By the interval quantity k, made by the counter from instant $t = 0$ of wave generation at frequency f_2 till the instant in which the echo is detected by proper comparating circuits (figure 6), we are thus in the position to evaluate the quantized obstacle distance R. In figure 5 we see schematically indicated the presence of two obstacles at the distances of 20 and 50 meters. Knowing that the echo signal intensity lessens as the obstacle distance increases, we utilize receivers whose amplifications are increasing with the distance, i.e. with R, i.e. with k. In this way we obtain a first step toward the normalization of amplitudes of echo signals; this is essential for all the following circuits. The block diagram of the circuit that performs what above described about the measures of R and Z is shown in figure 6.

The oscillator sends a square wave with the period τ to the modulator, to the counter and to a frequency divider; from the latter is available the pulse repetition frequency 1/T that is sent to the counter, to the modulator and to the logics & display. The modulator, on the base of the two received signals, sends in sequence once at a time a tension pulse (τ) to each cavity A, B, C, whose echo received signal outputs are sent to the amplifiers which receive also the gain control signal from the counter. Then the amplified signals enter into the comparator circuits which provide the identification of angles Z and of the distances R, utilizing the counter digital output. The three signals P.R.F., Z, R

are collected and elaborated by appropriate logic circuits for the final presentation on the display.

An important characteristic of the system is that it must result not affected by the car-made noise; therefore, for electromagnetic exigencies, it is essential that the transmitted waveform be not amplitude modulated (by short pulses) but it has to be frequency modulated. Our aim has been therefore to devise the frequncy pulsive modulation, and to obtain this by means of resonant cavities, whereas the resonant cavities are notoriously designed to operate by continuous waves and normally used in telecommunications or in Doppler radar systems.

In conclusion we have to clarify that the function diagram is in practice completely different from those of current radars: in fact there are not emitted high power radio frequency pulses (produced by klystrons, magnetron, etc.) alternated with dead periods, during which the transmitter is off and the echoes are heeded; moreover for determining the angle Z we have eliminated the need of a floating antenna (that would be bulky, delicate and unsightely) or a phase-array antenna (very expensive and low directional). The novities envisaged consist instead in the following: (a) transmitting continuous but frequency modulated waves (with the short pulses τ) by using simpler and more economical devices (resonant cavities) with the possibility of using high-gain high-directional antennas (horn type or parabolic type), (b) adopting the "amplitude discrimination" technics based on n beams, divergent and fixed,

for the angle Z determination. Therefore the system is not similar to the amplitude-comparison monopulse tracking radar, which employs overlapping antenna patterns to obtain the angular error. The system is not a copy of the radio-beacon, since our system is fully self-contained and does not require transponders, installed for example on others' vehicles. The system is neither a development of the radio altimeter based on Doppler effect, since the Doppler effect is not utilized: in fact we do not have to make only one measurement, as the distance aircraft-ground, but we have to perform as many and distinct measurements as the obstacles in continuous movements ahead of the driver, including their angular position Z, to obtaining the complete frontal map of the free space and of the occupied space, as clearly shown in figure 1.

It is understood that the system in accordance with this invention can be modified by the experts of this field to adapt it to any type of vehicle, on land, see or air, therewith remaining in the competence of the present patent.

Claims.

1. A vehicular anticollision radar system for driving in the fog, exhibiting a bidimensional obstacle display for direct vision or by reflection from the windscreen toward the driver, thus consenting him to see the display together with the road ahead, including: oscillator, modulator, counter, frequency divider, resonant cavities with Gunn diode and Schottky diode and varactor diode, amplifiers, comparator circuits, signal elaborating logic circuits, display, operating as follows: the oscillator sends a square wave with the period τ to the modulator, to the counter and to a frequency divider; from the latter is available the pulse repetition frequency 1/T that is sent to the counter, to the modulator and to the logic elaboration circuits; the modulator, on the base of the two received signals, sends in sequence once at a time a tension pulse (τ) to each cavity, whose echo received signal outputs are sent to the amplifiers which receive also the gain control signal from the counter; then the amplified signals enter into the comparator circuits which provide the identification of angles Z and of the distances R, utilizing the counter digital output; the three signals P.R.F., Z, R are collected and elaborated by appropriate logic circuits for the final presentation on the display.

2. Self-contained electronic fully solid state system, according to claim 1, wherein no need exists of moving antenna neither of transponders, also including a display with adjustable luminosity.

3. Self-contained electronic fully solid state system wherein use is made of n divergent microwave beams exploring 2n-1 sectors ahead the vehicle for identifying the obstacle angles Z, besides the distances R, with elaboration of the received echo signals by logic devices thereby including: (a) means for signalling of the obstacle distances R and their belonging sectors, (b) means for signalling in excess in case of echoes coming from common sectors, (c) means for the extension of signalling of an obstacle along its shade cone.

4. Presentation on display of logic elaboration results, in accordance with claim 3.

5. Employment and application in the system of resonant cavities furnished with Gunn diode, Schottky diode and possibly varactor diode, or other analogous systems and apparatus, that are more economical and at the same time efficient, apt to emitting pulsive frequency modulated microwaves in order to detect the echoes caused by obstacles through the beat effect.

6. Self-contained electronic fully solid state system wherein happens the beat effect between ther received echo wave trains at frequency f_2 and the local oscillation at frequency f_1, actuated by above mentioned devices.

7. Self-contained electronic fully solid state system comprising digital comparators and counters for the measurement of distances R and angles Z.

Drawings.

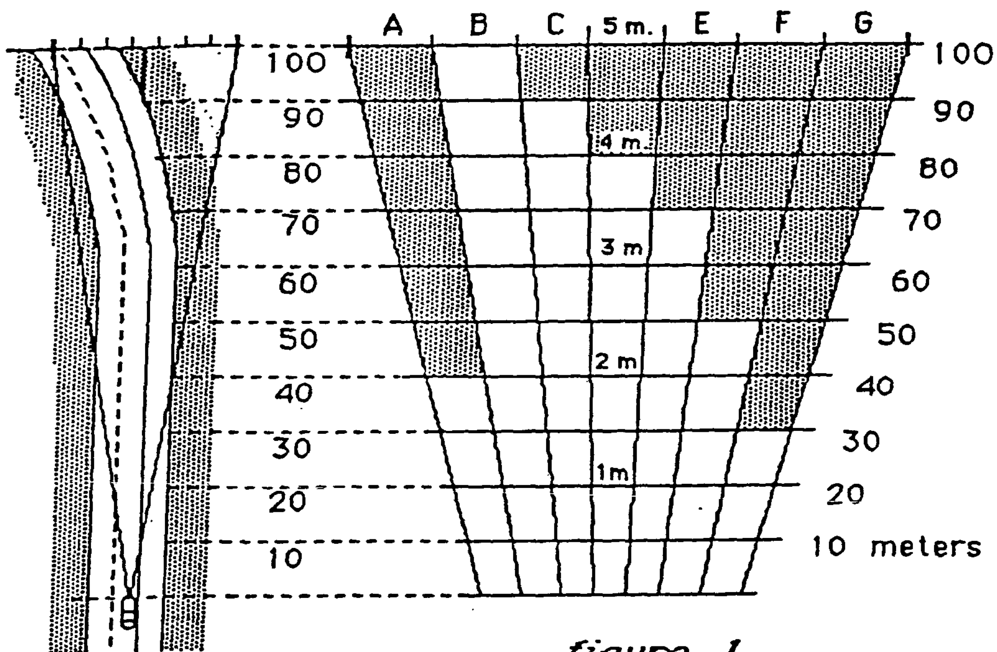
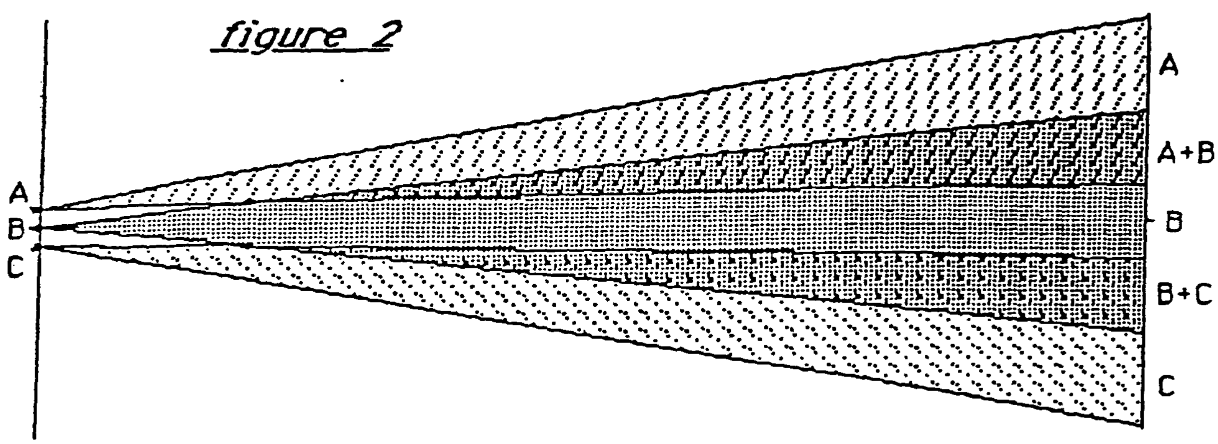


figure 1

figure 2



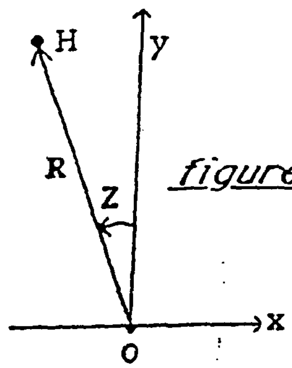


figure 3

figure 4

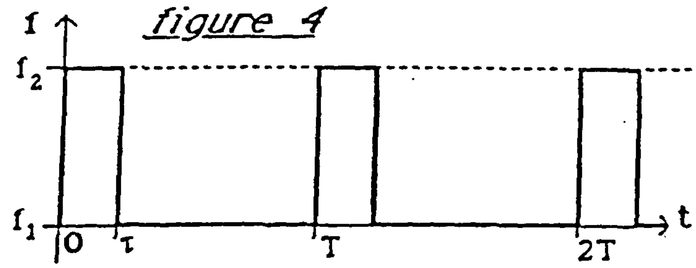


figure 5

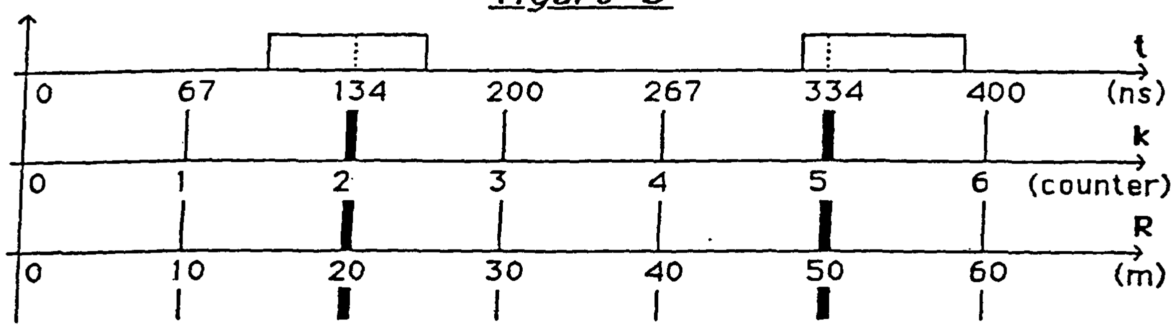
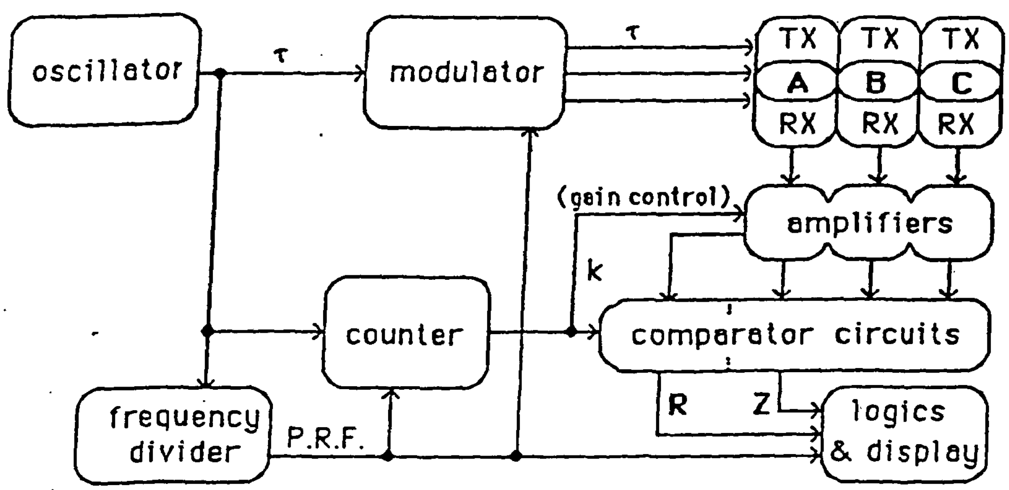


figure 6



INTERNATIONAL SEARCH REPORT

International Application No PCT/IT 89/00002

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: G 01 S 13/93; G 01 S 7/04; G 01 S 13/87

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	G 01 S

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	WO, A, 80/01782 (COLLISION AVOIDANCE SYSTEMS) 4 September 1980 see pages 3-6,9-18	3
A		1,5-7
	--	
Y	US, A, 4674073 (NARUSE) 16 June 1987 see columns 2-3	3
	--	
A	DE, A, 2557038 (LICENTIA PATENT) 23 June 1977 see figure; pages 3-5	1,2
	--	
A	IEEE Transactions on IECI, volume IECI-11, no. 1, February 1964, A.L. Merlo: "Automotive radar for the prevention of collisions", pages 1-6 see page 3, right-hand column, lines 26-33	1,6
	--	
A	EP, A, 0129251 (SIEMENS) 27 December 1984 see figures 1,2; pages 7-10	1,5,6
	--	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
24th April 1989	30.05.89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	M. VAN MOL

Form PCT/ISA/210 (second sheet) (January 1985)

International Application No. PCT/IT 89/00002

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	DE, A, 3414159 (LICENTIA PATENT-VERWALTUNGS-GmbH) 24 October 1985 see figures 1,3; pages 4-6 --	1,5,6
A	DE, A, 2327186 (LICENTIA PATENT-VERWALTUNGS-GmbH) 19 December 1974 see pages 2-8 --	1,3,5-7
A	DE, A, 2553302 (STANDARD ELEKTRIK) 2 June 1977 see pages 5-10 --	1-7
A	DE, A, 2951769 (FRAUNHOFER) 2 July 1971 see figures; pages 5-6 --	2
A	Patent Abstracts of Japan, volume 10, no. 135 (P-457)(2192), 20 May 1986, & JP, A, 60257381 (DAIHATSU KOGYO K.K.) 19 December 1985	1-4

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. IT 8900002

SA 26499

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 23/05/89
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A- 8001782	04-09-80	EP-A,B 0024430	11-03-81
		AU-A- 5586280	04-09-80
		US-A- 4308536	29-12-81
		CA-A- 1135819	16-11-82
US-A- 4674073	16-06-87	JP-A- 61200490	05-09-86
DE-A- 2557038	23-06-77	None	
EP-A- 0129251	27-12-84	DE-A- 3322304	03-01-85
		JP-A- 60015576	26-01-85
		US-A- 4731611	15-03-88
		DE-A- 3473932	13-10-88
DE-A- 3414159	24-10-85	None	
DE-A- 2327186	19-12-74	AU-A- 6879274	13-11-75
DE-A- 2553302	02-06-77	US-A- 4101888	18-07-78
DE-A- 2951769	02-07-81	None	

EPO FORM P0479